Rock physics modelling of siliciclastic shallow-marine clinoforms on the New Jersey continental shelf using 3D seismic data and well logs

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Heterogeneities within clinoforms, which can be in the form of variations in internal geometry and/or change in sediment distribution, may act as fluid flow barriers or conduits for hydrocarbon or freshwater reservoirs. These heterogeneities can lead to considerable uncertainty in estimating pore-fluid recovery factors by up to 35%. And yet, variations in sediment petrophysical characteristics within clinoforms have been poorly documented. Understanding the rock physics of clinoform heterogeneities along continental margins is a key to reducing the uncertainties in predicting the dynamics and the volume of recoverable pore fluids within these structures.

The Miocene sedimentary record of the New Jersey continental margin is a prime candidate for studying continental-margin clinoform structures and the variation in their petrophysical properties. The margin has experienced a stable tectonic history, smooth and gradual thermal subsidence, and continuous sediment loading in the Miocene, resulting in deposition of well-developed siliciclastic clinoformal sequences. We use data from three IODP Expedition 313 boreholes and an encompassing high-resolution 3D multichannel seismic volume, collected in 2015 by the R/V M.G. Langseth on the New Jersey continental shelf, to predict shallow-marine sedimentological properties of the Miocene clinoforms at a significantly higher resolution (~5 m laterally) than previously achieved (~100s of m). We identify 76 system tracts and 22 sequences spanning ~8 m.y. of the Miocene. The results of our 3D stratigraphic analysis provide a detailed structural framework for analyses of the Miocene deposits to: 1) define the sedimentary structure in terms of stratal packages and 2) estimate the internal clinoform heterogeneity associated with phases of known mid-Cenozoic sea-level change.

Our statistical analysis of the estimated elastic properties, including P-wave velocity (Vp), density and clay volume, reveals repeating spatial patterns in the internal rock physics properties of the Miocene clinoforms. We show that diagenesis and sediment compaction within the dipping parts of clinoforms cause a continuous increase of Vp in the seaward direction, with a magnitude that decreases from top to bottom. Our results also suggest that lithofacies change in clinoforms
imposes a stronger influence on density, as lateral changes in lithofacies are more pronounced in sediment density than in Vp. In the Miocene sedimentary record, the transgressive system tracts show a seaward coarsening trend in grain size and a 3%-5% increase in density from clinoform topsets to bottomsets. Highstand and lowstand system tracts show a fining trend basinward, with a ~8% and 5% reduction in density, respectively. We further demonstrate that the identified trends can provide a standard model allowing incorporation of clinoforms in reservoir characterization techniques, such as model-based seismic inversion, and enable setting of guidelines on how the petrophysical properties change regionally in shallow-marine siliciclastic environments of continental margins.